DDF annual report

Title of Investigation:

Microwave Structures Using Stereolithography

Principal Investigator:

Alan Kogut (Code 665)

Other In-house Members of Team:

Edward Wollack (Code 665) and David Clark (Code 547)

Other External Collaborators:

None

Initiation Year:

FY 2005

Aggregate Amount of Funding Authorized in FY 2004 and Earlier Years:

$0

Funding Authorized for FY 2005:

$25,000

Actual or Expected Expenditure of FY 2005 Funding:

In-house, $25,000

Status of Investigation at End of FY 2005:

Transitioned to Core Capability funding

Expected Completion Date:

September 2006

Purpose of Investigation:

Our goal is to produce microwave components using stereolithography and evaluate their suitability for spaceflight applications. Stereo lithography, sometimes called "3D printing," uses lasers to illuminate and harden a plastic resin to produce a 3-dimensional object in the desired shape.

With stereolithography, the finished piece can be plated to provide electrical conductivity, using standard (low-cost) techniques. In contrast, microwave components, such as antennas, waveguides, and couplers, are commonly made from solid pieces of metal. This technique, although reliable, is slow, expensive, and heavy. Microwave components produced with stereolithography, however, are less expensive and time consuming to produce. They can be delivered within 3 days; therefore, making the technique better than current state-of-the-art techniques.

Accomplishments to Date:

We have built and tested waveguide components using stereolithography. Figure 1 shows a simple WR28 waveguide, suitable for operation at 1-cm wavelength. The measured insertion loss for this piece is -0.03 dB, corresponding to a somewhat larger attenuation than would be typical for a similar copper piece. The modest increase in attenuation results from imperfections at the waveguide flanges on either end. This is not unexpected; lapping the flanges to smooth the surface improves the performance of the manufactured piece.

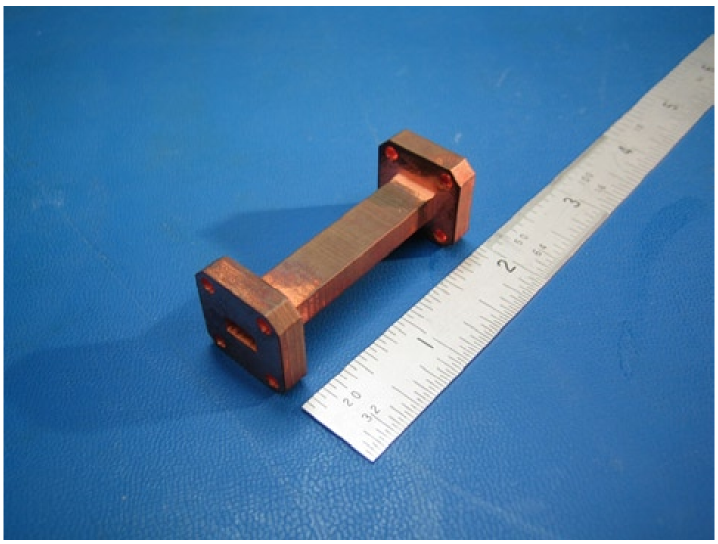

Figure 1. A section of straight waveguide produced using stereolithography and plated with copper. The microwave performance of similar pieces is comparable to waveguides made from solid copper.

More complicated designs are possible. Figure 2 shows a split-block design suitable for use at millimeter wavelengths. At these shorter wavelengths, the aspect ratio of the waveguide becomes large, requiring the component to be built in two pieces to enable tolerances to be maintained all along the long, thin waveguide. Initial tests indicate that the design is workable, but requires an intermediate step to machine the surfaces after stereolithographic fabrication but before plating.

Typical spaceflight applications require that a component survive over temperatures that range from -40°C to +40°C. Many potential applications at millimeter wavelengths require that components operate at cryogenic temperatures of -200°C or colder. We have tested the split-block design by repeatedly cycling it between warm (+40°C) and cold (-200°C) temperatures. No evidence for delamination or structural failure is seen.

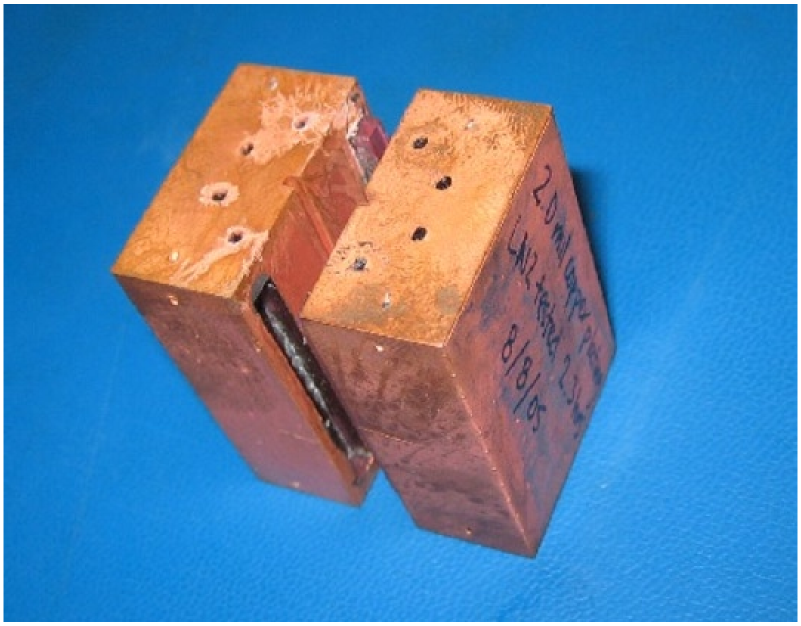

Figure 2. A split-block design for use at 3-mm wavelength. The central waveguide's aspect ratio is too large for reliable plating along its entire length, requiring the piece to be manufactured in two mating halves.

Planned Future Work:

Our initial results indicate that stereolithography is well suited as a fast-turnaround manufacturing technique for microwave components. Over the next year, we will build and test more complex pieces designed to push the limits of stereolithographic production.

Key Points Summary:

Project's innovative features: This project applies advanced manufacturing techniques to develop low-cost, fast-turnaround microwave components. Cost and mass savings are typically 80 percent compared with standard manufacturing techniques. The low-cost and fast turnaround are particularly well suited for prototype designs and flight engineering models, while the mass savings are important for spaceflight applications.

Potential payoff to Goddard/NASA: Rapid, low-cost manufacturing techniques are essential to maintain Goddard's leading position in microwave and sub-mm astrophysics. Goddard led both the Cosmic Microwave Background Explorer (COBE) and Wilkinson Microwave Anisotropy Probe (WMAP) missions to measure the cosmic microwave background. A Goddard team is now developing instrumentation and observing techniques to measure the polarization of the microwave background in preparation for the planned Beyond Einstein Inflation Probe. The cycle time to design, build, and test the required microwave components is typically 6 months, dominated by the long manufacturing times required to machine these components from solid pieces of metal. The reduced development time, lower cost, and lower mass associated with stereolithographic-production techniques will significantly speed the development of the next generation of microwave instrumentation. In addition, stereolithography allows the production of light-weighted interior shapes (e.g. webbing) that standard machining cannot duplicate.

Criteria for success: The project is a success if the components manufactured using stereolithography perform similarly to those made using standard techniques.

Technical risk factors: Several factors could degrade the microwave performance of stereolithographic components. The process builds 3-dimensional pieces a single layer at a time, leaving faint ridges in the finished piece where smooth walls are required. These ridges ultimately may limit the wavelengths for which stereolithographic techniques are suitable. The spatial resolution achievable with this process is limited by the beam size of the laser used to harden the resin. It may not be possible to achieve the tolerances of a few thousandths of an inch required to produce components for use at millimeter wavelengths. Finally, the components must be plated to produce a conductive surface. Thermal stress from large swings in the component temperature can lead to delamination of the plating from the underlying resin.